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ON THE ASSOCIATION FUNCTIONS OF THE CEREBRUM

THE relation of the brain to mental processes or, more broadly, that of mind and body, is a topic of perpetual interest. Numerous explanations of this relation have been suggested and discussed, and much has been written by the monist and by the dualist, by the interactionist and by the parallelist. When taken from his scholastic environment and off his philosophic guard, even the idealist will, at times, admit that, as a working, every-day hypothesis, we may say that the brain is closely associated with mental states or with consciousness. It is with this topic the present paper deals, but with the intention, and, in fact, with the explicit avowal, not to review the different hypotheses or to discuss the subject from a philosopher's standpoint. It is in a less general way that the subject will be approached, viz., by recording certain facts regarding the activities of the cerebrum and certain facts of a mental order, and by deductions from these facts.[1]

Our present knowledge regarding the functions of the cerebrum may be briefly summarized as follows: (*a*) the relation of muscles or of movements of bodily segments to certain areas of the cerebral cortex is well recognized; (*b*) we know something of the relations of sensations to other cortical areas, or, to speak more exactly, we know something of the relation of injuries of these areas to disturbances of certain sensational processes; (*c*) little is known of the relation of perceptual and associational mental states to any part of the cerebrum, and none of the hypotheses regarding this relation is in conformity with the known facts and none is widely accepted. Before taking up the special topic of the present paper, the formulation of an hypothesis regarding the functions of the so-called association areas, it will be well to epitomize the generally accepted facts regarding cerebral localization. Some of these facts are of special value for the understanding of the hypothesis that is to be presented.

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[1] In this connection it may be stated that the description of events will be observed to be rather interactionist, but it is to be noted that this is done without epistemological implications, and solely for convenience of expression.

Anatomical Divisions of the Cerebral Cortex.—The fissures of the cerebrum are so well marked, and many of them so constant in location, that gross anatomical divisions of the brain into frontal, parietal, etc., lobes were made with these as bounding lines. It was thought that these areas were quite distinct and that the division had a functional as well as an anatomical value. During the past few years, however, numerous histological studies of the structure of the cortex have shown the crudeness of the divisions by sulci, and a finer differentiation into areas according to cell and fiber lamination has been made. Some of the results of these studies are shown in the accompanying figure in which are marked the divisions on the lateral aspect of the left hemisphere.[2] It will be seen that the frontal lobe (anterior to the fissure of Rolando) is divided into four areas not differentiated by lines of sulci; the parietal, temporal, and occipital

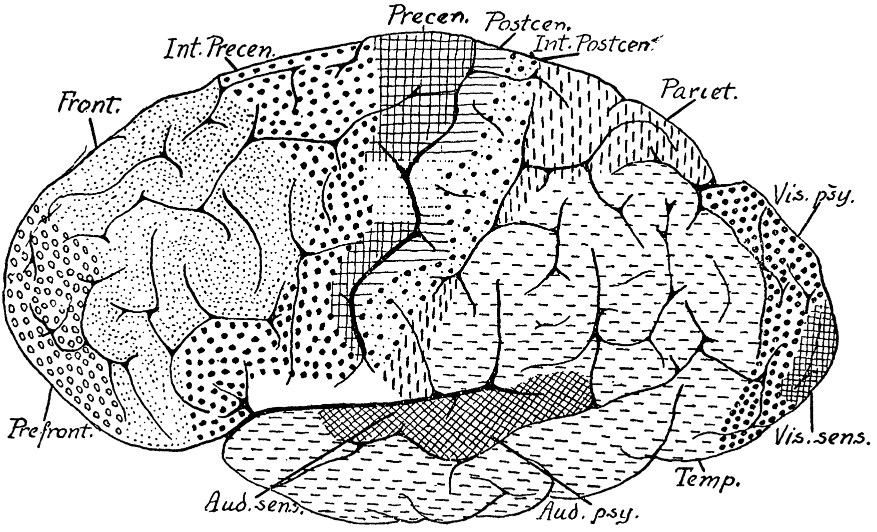

FIG. 1. Cortical areas, differentiated by cyto- and myelo-architechtonic. Adapted from Campbell.

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[2] From A. W. Campbell: "Histological Studies on the Localization of Cerebral Functions." Cambridge, 1905. Campbell's results are, in the main, similar to those of other investigators, although it should be stated that in certain details they have been criticized. For the technicalities and for finer differentiation the reader is referred to the following publications. K. Brodmann: various articles in *Journal für Psychologie und Neurologie*, 1902–1909, and "Vergleichende Lokalisationslehre der Grosshirnrinde in ihren Principien dargestellt auf Grund des Zellenbaues," 1909. J. S. Bolton: *Philosophical Transactions*, CXCIII., 1900; *Journal Mental Science*, 1905–1908; Recent Researches on Cortical Localization, in L. Hill's "Further Advances in Physiology," 1909.

areas are divided into eight distinct zones, some of which are, and some of which are not, bounded by constant fissural lines. These cortical areas are supposed to have different functions, but the comparison of clinical and physiological data with the structural studies is not yet satisfactory in regard to all areas. We shall need, therefore, to take for consideration at one time several areas and attempt to show the functions so far as they are known.

Frontal and Prefrontal Areas.—Of definite functions of this large area we have comparatively little knowledge.[3] Ferrier found movements of the head and eyes to follow stimulation of the frontal lobes, but it is not certain that these results were due to the stimulation of an area other than the intermediate precentral region, experiments on which are mentioned below. Respiratory and heart rhythm changes have been found to accompany stimulation of the frontal regions (Langelaan and Beyerman), and these results have been taken as indications of an "attention" function of this area. Spinal reflexes are inhibited or their latent periods prolonged when the frontals are concomitantly stimulated and the latent periods are shortened after extirpation of the frontals. An inhibition function has, therefore, been assumed to have its seat here. Intellectual defects are said to follow injury to or destruction of the frontal lobes, and there is much clinical and physiological evidence in support of this (Phelps, Mills, et al.). The frontals are underdeveloped in cases of mental deficiency and they undergo atrophy in cases of dementia (Bolton), which facts have led to the statement that this "region is concerned with attention and the general orderly coordination of psychic processes." Following the extirpation of the frontals in cats and monkeys I have found no definite motor inabilities, but there were distinct losses of associations (habits). Finally, we may mention that centers for motor speech associations have been located in the left frontal, one for writing and the other for verbal speech.[4] The verbal speech area is included in the intermediate precentral area by Campbell, but Brodmann and Elliott Smith note distinct differences in structure between this and the intermediate precentral.

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[3] I have considered in some detail the facts regarding the functions of the frontal and prefrontal regions in a monograph ("On the Functions of the Cerebrum: The Frontal Lobes," *Archives of Psychology*, 1907) and the present account is a brief presentation of these facts.

[4] At this time we shall not need to consider the current controversy regarding aphasic conditions and the brain localization of speech functions. In this article I take the generally accepted views. I am aware that some doubt has been cast upon the value of the older conclusions drawn from the available aphasia data, but on the other hand we have a number of facts that can well be understood only upon the older basis. Marie's contribution appears to be valuable in a negative or critical way in that he calls attention to loose methods of clinical and pathological examination, but the positive value of his deductions appears slight.

Precentral and Intermediate Precentral Areas—From early times a connection between voluntary movement ability and the cerebrum was suspected. Head injuries were noticed to be followed at times by paralyses and at times by convulsive movements that could not be voluntarily controlled. When autopsies were performed, definite lesions were found associated with these movement disturbances. These observations were supplemented by stimulation experiments by which it was found that the excitation of certain cortical areas in the dog was accompanied by movements of the head, trunk, or limbs. The original observations of Hitzig have been confirmed and supplemented by numerous investigators. The later work, by refinement of methods and especially by the use of the brains of monkeys and man, has given us an accurate map of the areal distribution of motor function. On the brain of the chimpanzee, which in this respect closely resembles that of man, Sherrington and Gruenbaum found the motor area to be anterior to the fissure of Rolando. These results have been confirmed by the Vogts, who not only stimulated many points, but who have recorded the location of each stimulus and the character of each resultant movement. The combined results of the Vogts showing the relation of the pre-Rolandic cortex to movements are represented in Fig. 2. On careful stimulation of the cortex, both the English and the German investigators found coordinated, but rather simple, types of movement of different parts of the body.

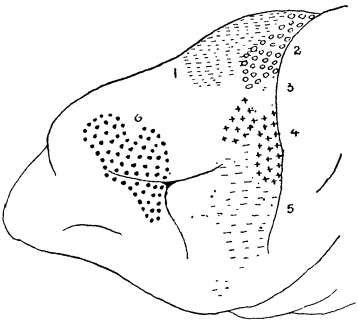

FIG. 2. Cortical motor areas in the monkey. Adapted from Vogt. 1, tail and vertebral column; 2, foot, leg, and thigh; 3, trunk; 4, arm and hand; 5, face, neck, tongue, jaw, ear, and eyelid; 6, eyes and lids.

These results have been partly confirmed on man by a similar method of stimulation, and the results of clinico-pathological examinations are in accord with them. Indeed, so much has already been accomplished in this direction that we are justified in concluding that there are similar arrangements of the cortical motor areas in man and in the higher apes. The movements produced by stimulation of the precentral cortex, as has been mentioned above, are simple, but coordinated, and similar to those of a simple reaction. In addition to the areas producing this simple type of movement, Sherrington and Gruenbaum and the Vogts found a second area in the frontal cortex, the stimulation of which was accompanied by movements of a more complex character. In the diagram this area is marked 6. Stimulation of this region produced associated movements of the eyes, conjugate in character, movements of the eyelids, and, at times, combined movements of these parts and of the head. These movements and this area are probably the same as the movements and area found by Ferrier and mentioned in connection with the frontal regions. Both are doubtless the intermediate precentral area.

Postcentral and Intermediate Postcentral Areas.—Both the pre- and post-central gyri were formerly thought to have a motor or a combined motor and sensory function. The experiments on the precentral areas have, however, established the true limits of the motor area, and it is almost universally admitted that the postcentral cortex has not a direct, but only a remote, connection with the initiation of motor impulses. Observations on man have definitely settled that the postcentral convolutions are concerned with certain sensational processes, the receptor organs for which lie in the skin and in the underlying tissues. The most interesting and the most conclusive evidence of the association of this area with the skin sensations has been obtained by Cushing, who stimulated this area in a conscious individual whose brain had been exposed preparatory to an operation. At the time of the stimulation, the subject reported peculiar sensations from the arm which were obviously not due to an external stimulus. It is also to be noted that certain hypesthesias and anesthesias in man have been associated with tumors, hemorrhages, and other lesions of this part of the cortex. Lesions of the neighboring area, the intermediate postcentral (possibly also of the neighboring association area), produce the condition known as astereognosis. Stereognosis, it will be remembered, is the name given to the ability to recognize objects from the sensations received from the skin and motor apparatus. Although in clinical works this is called a sensation, we know it is a complex of sensations and is allied to the associations of speech.

Auditosensory and Auditopsychic Areas.—This part of the temporal lobe is associated with the sense of hearing. By means of the training-extirpation method extensively used by me, Kalischer was able to show that when this area was extirpated, animals failed to respond to tones to which they had previously learned to respond.

Earlier investigators had noted the failure of animals to respond to sounds after destruction of the temporal lobes, and, although their methods are more open to criticism than those of Kalischer, the facts warrant the conclusion of a close connection between this part of the cerebral cortex and hearing. Nothing more of a definite character is known of the functions of the so-called auditopsychic region, unless we are to assume that Campbell intends to include therein part or all of the area for sensory (auditory) speech. In addition to the apparent auditory function of this area, it has been found that stimulation is followed by movements of the ears (Schäfer). The movements are similar to those produced by stimulation of the precentral (probably more like those from the stimulation of the intermediate precentral) area. They have, however, a longer latent period, and this fact indicates that the movements are not directly initiated from this area.

Visuosensory and Visuopsychic Areas.—Of the cortical sensory functions, that for vision is the most accurately marked out. Many observations on the relation of vision to the cortex have been made, and Henschen in particular has given us the results of clinical and pathological studies that show an almost accurate representation on the cortex of the different parts of the retina. Extirpation or destruction of this area on one side is followed by an hemianopia; extirpation of both, by complete blindness. The neural pathways from the eyes to the occipital cortex have been carefully investigated, and there seems little reason to doubt a close relation between the occipital lobes and visual sensations. Reference to Fig. 1 will indicate that in the occipital region at least two areas are supposed to be connected with the visual apparatus. To these areas Campbell gives the names visuosensory and visuopsychic, respectively. The visuosensory area has been referred to above as physiologically and clinically well understood, but it should be stated that there is little evidence for a functional differentiation of this area from the so-called visuopsychic. Some observers have located in the visuopsychic region an area which is supposed by them to be concerned with color vision, but this localization is not widely accepted. In the same area a center for visual speech has also been located by some, but it is certain from recent work that the speech center must be localized, if at all, within the adjacent association area. From stimulation of this visual area Schäfer obtained coordinated movements, and found, as in the case of the temporal lobes, a longer latent period than for the movements produced by stimulation of the precentral cortex.

Parietal and Temporal, or the So-called Posterior Association Areas.—Of this large portion of the cerebral cortex the functional relations are not understood as well as those of the frontal association area. In connection with the consideration of the temporal (auditosensory and auditopsychic) region, mention was made of a possible relation of this area to speech function; in connection with the occipital (visuosensory and visuopsychic) area a similar functional relation was mentioned as a possibility; and in connection with the intermediate postcentral convolutions stereognosis was considered. On account of the inaccuracy of the cerebral examinations it is not sure that these functions belong to the areas mentioned, and, in fact, it is likely that part or all of these functions are subserved through the cells in the posterior association area. Following extirpations in animals, I have found losses of associations similar to those resulting from extirpation of the frontal lobes, and this fact would indicate the use of this area in the formation of habits. Although not much weight can be placed upon it at the present time on account of the small amount of material that has been examined, it may be mentioned as an additional fact that in certain types of intellectual men the posterior association area has been found to be more highly convoluted (supposedly better developed and extensively used) than the frontal portion of the cerebrum.

Although the consideration of the known functions of the cortical areas has been necessarily brief, sufficient indication has been given that the motor and the sensory (hearing, touch, vision) cortical mechanisms are understood and localized. Opposed to this definiteness there is a vagueness in regard to the functions of the association areas. Some few facts are known, but there appears to be more or less haze about the subject, and writers tend to avoid it. Following is a summary of the known facts regarding the two large association areas: (*a*) in the frontal association area are located centers of motor speech and writing; (*b*) in the posterior association area are centers for what clinicians call the understanding of auditory and visual speech; (*c*) the frontal regions are clearly associated with the production of movements, especially those of a complex character; (*d*) in the posterior association area (or in the closely associated intermediate postcentral cortex) is an area for the understanding, through the medium of the skin and motor sensations, of the character of objects; (*e*) the results of my work on monkeys and cats indicate that both the frontal and the posterior association areas are concerned in the formation of simple sensorimotor habits.

These facts give the clue for the understanding of the relation of these association areas and of their functions. All the physiological and all the clinical data point to the use of the frontal lobes for the initiation of complex motor processes. All the physiological and all the clinical data point to the use of the posterior association areas for the combination or the association of sensory processes.

The results that have been mentioned and the two conclusions that have been drawn from the results, led to the formulation of the following scheme or hypothesis regarding the cerebral processes that take place in these areas, and which result in the so-called higher intellectual processes, or, as we may call them, associations.[5] Fig. 3 indicates the conception of the cerebral connections. It is generally admitted that we have cerebral areas which receive impulses through the afferent sensory neurones and areas (*M*) which give rise to or initiate impulses which go by way of the efferent neurones to the muscles and glands of the body. The direct connections and activities of this kind of neurones in the spinal cord give rise to reflexes, and it is probable that similar reflexes occur through the activity of the cerebral neurones, although this matter is not settled. It is most likely that in the cerebrum at least two, and perhaps four, other neurones must function to produce a cortical reaction accompanied by conscious assimilation and conscious effort.

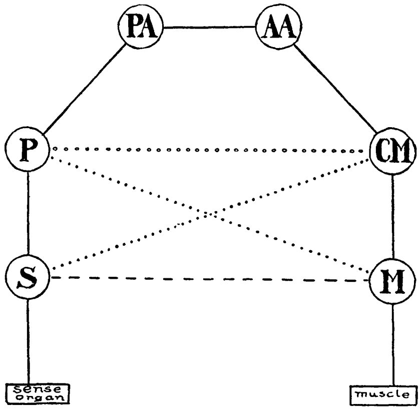

Fig. 3. Scheme of cerebral connections associated with mental processes. *S*, sensory area; *P*, perceptual area; *PA*, posterior association area; *AA*, anterior association area; *CM*, area for coordination of movements; *M*, simple motor area.

In the formation of an association many, perhaps thousands, of cells in different areas of the cortex are active. An associational connection between the sensory and the motor ends is, I believe, always mediated through at least six neurones or sets of neurones. To take a visuomotor association as an example, it is conceived that the following cortical areas are successively set in activity: visuosensory, visuopsychic, posterior association, anterior association, intermediate precentral, precentral. The activities of the visuosensory and the visuopsychic give us perceptions, the activities of the intermediate precentral and the precentral give us reactions, and the two association areas are connecting links between the sensory and motor ends, and between the two hemispheres.

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[5] The view here expressed has been briefly given in the *Psychological Bulletin*, Vol. V., 1908, p. 219, note.

That both association areas are used in associations (physiologically and psychologically) is established by the phenomena of aphasia and apraxia. That both are utilized in the formation of definite modes of reaction is shown by the loss of associations by animals when either is destroyed. The anatomical connections of these areas with each other and their connections with other cortical cells have been sufficiently well studied to show a close relation of the areas to each other and to the projection spheres. That both are important, not silent and useless, parts is proven by the occurrence of mental defects with disease or destruction of either.

Evidence is at hand to show that the frontal areas have a more direct connection with the motor areas than do the posterior. The variations of reflex movements concomitantly with variations in frontal lobe activity have been mentioned. That the frontals have a more direct relation to motor processes, and are for motor associations, is a reasonable deduction from the apraxia studies of Liepmann and others. The older cortical localizations of vocal speech and writing, although they may need some modification to conform to recent findings, also support this view; and, finally, we may mention that the frontal region degenerates more than other portions when there is an inability of adjustment (dementia), and that it is underdeveloped when there is a condition of imbecility.

It is by a continual process of adjustment that man has attained his place in the world, and the variety of activities so characteristic of him is made possible through the frontal regions. The direct motor responses of an animal need no large amount of association elements, but the indirect reactions of man require an amount of coordination that is supplied by the association cells. There is the increased use of the hands, of tools, of the legs, and of other mechanisms for propulsion, requiring new adjustments and new associations; and the impulses to act are paralleled by a similar number of impulses to check activity, or tending to check the primary, reflex-like impulses.

The posterior areas are, from the accounts given above, clearly more closely allied with the sensory spheres. The large size of this region in intellectual men is only one indication of this, but the sensory aphasias and other similar processes that are located here by clinicians confirm this view.

We may now return to the scheme of cerebral connections that has been suggested (Fig. 3). Here are represented all the kinds of cerebral connections that clinical and physiological studies have indicated. The centers *M* and *S* are to be conceived to be multiple, and to include all the so-called subsidiary centers, *e. g.*, those in the basal ganglia and in the spinal cord. The direct functional connection of these centers results in reflexes of different kinds. But as the stimulus reaches the organism at certain times and under certain conditions, the impulses are transmitted toward the centers *P*, which are located in different parts of the cortex depending upon the stimulated end organ. In turn the posterior association area is stimulated (*PA*), and thence the coordinating motor area (*AA*), and then a second, but less extensively general, coordinating center (*CM*), and finally the center (*M*) from which the impulses arise that go by way of the spinal neurons to the muscles and glands of the body. This sixfold association process appears complex, but it is doubtless simpler than the actual physiological processes. None of the centers noted on the diagram represents one cerebral neuron; most of them must represent many, perhaps thousands, of neurones which act together to produce the required effect of a reaction following a definite stimulus. Nor must it be understood that all cerebral activities take the long path. From the studies on animals of the relation of the association areas to the learning and retention of habits, it is plain that after an association (habit) is formed, the upper (*AA* and *PA*) areas may be dispensed with, and the reaction obtained through the lower centers (*P* and *CA;* or *S* and *M*). It is likely that most men use the association areas less than once during a thousand stimulations of a sense organ. It is certain that some men use the association areas even less than this, and those of defective development, such as idiots, have probably none of their frontal or posterior association cells active throughout the day.

The hypothesis of cerebral mechanics that has been advanced, helps to understand the various conflicting views of aphasia: the diaschisis of von Monakow, the Broca localization, the dementia view of Marie. From this point of view we may also understand the localization of attention and inhibition centers in the frontal lobes, and at the same time we appreciate why there have been ardent advocates and opponents of ''intellectual centers'' in the frontal and the posterior association areas. In believing in localization, we need not accept the crude views of Gall and Spurzheim; in fact, localization studies of recent years prevent this. Nor do we need to accept the views of Brodmann who believes that each of his thirty-eight anatomical areas represents a different physiological or mental function. At the present time, it is premature to speculate regarding all the distinct anatomical areas, but we have sufficient anatomical, physiological, and psychological evidence to warrant the conclusions that have been drawn regarding distinct functions for the hitherto little understood association areas.

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THE PLACE OF THE TIME PROBLEM IN CONTEMPORARY PHILOSOPHY[1]

THIS paper is designed first of all to present a strategic analysis of the main situation in contemporary Anglo-American philosophy: an analysis which shall to some extent break up current systems into the discriminable tendencies or separate dialectical motives that have gone to the formation of them, which shall draw out the lines of opposition or congruency between the several elements of current opinion, shall ascertain upon what points there is most nearly general agreement, and shall discover by what lines of argument those who conceive it important to refute a given doctrine may proceed against the enemy with a maximum of directness, with a minimum waste of ratiocination, and with the strongest supporting columns. Just how all this bears upon the special topic assigned for this discussion will appear in the sequel.

I

Ignoring minor excursions and alarums, the situation—the exceedingly interesting and live situation—which we are concerned to analyze may be said to be something like this: Upon one side, but a little in the background—still influential, yet, whether deservedly or otherwise, assuredly of diminishing influence—stand the lately dominant neo-Kantian types of systematic philosophy, of which the most essential elements may be called, for short, rationalism in epistemology; "eternalism" in the conception of the meaning of truth and the nature of "ultimate" reality; idealism; and "this-worldliness," or a belief in the necessity of giving a positive place, value, and significance in reality to the concrete, finite, temporal existences of ordinary experience. (This use of tags and labels, in place of explicit statements of the propositions asserted is, I know, odious and, with inexpert audiences, usually befogging; but on this occasion I hope it may be permitted, in the interest of brevity, especially since the "-isms" in question are for the most part presently to be

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[1] A paper read as part of a prearranged discussion of the topic, before the American Philosophical Association, at its meeting at Yale University, December, 1909.